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THE MORRISON OF OKLAHOMA
AND ITS DINOSAURS

A PART OF A DISSERTATION SUBMITTED
TO THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY
1938

By
J. WILLIS STOVALL

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J. WILLIS STOVALL
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ABSTRACT

The discovery of Morrison dinosaur bones in Cimarron County, Oklahoma, led to a study of the geology of the area. This investigation brought to light six deposits containing remains of these animals, of which four genera have been identified. The study showed that the Morrison extends down the Cimarron River, beyond Highway 38, north of Boise City. At Robbers' Roost, 4 miles east of the New Mexico state line, the Morrison is unusually thick but thins rapidly toward the east, owing to erosion of a post-Morrison dome. For this reason, and because the Morrison has only a few feet of sediment between it and the Triassic, and because it is overlain by Lower Cretaceous sediments, it seems best assigned to the Jurassic.

INTRODUCTION

In 1931 Morrison dinosaur bones were discovered in the northwest corner of Cimarron County, Oklahoma. The find was made by a crew of road workers on Highway 64, about 100 yards east of the bridge crossing South Carrizo Creek, 10 miles east of the New Mexico-Oklahoma state line. This discovery was reported by the writer in 1932.¹ Since that time five additional deposits of dinosaur bones have been discovered in the general region. Extensive quarry operations have been carried on at the site of the first discovery; and more than 3,500 individual bones, most of them from a single genus, *Brontosaurus*, have been collected. Three other genera, *Ceratopsaurus*, *Camptosaurus*, and *Stegosaurus*, have been identified from the area. This work has been financed in part by the Works Progress Administration and in part by the state of Oklahoma.

The finding of the Morrison dinosaur bones in Cimarron County, considerably east of any previously known occurrence, led to a detailed study of the area. As a result considerable light has been thrown on the character of the Morrison formation.

Although the dinosaur bones just mentioned were the first Mor-

¹ J. Willis Stovall, "Jurassic in Oklahoma," *Science*, N.S., Vol. LXXVI (1932), pp. 122-23.

rison fossils to be found in Oklahoma, Lee² suspected the presence of the Morrison along the Cimarron in Oklahoma as early as 1901, when he discovered that formation on the Purgatoire River in southeastern Colorado. The next year further field work confirmed his belief and also showed the Morrison to be present on the Canadian River of New Mexico.³ Since that time many geologists have recognized the formation in the region, and in 1921-22 Rothrock⁴ reported several isolated patches of Morrison on the Cimarron River in Oklahoma and on the North Carrizo and Gallinas creeks. The map which accompanies Rothrock's report shows the Morrison cropping out at the following places: (1) at the west edge of Kenton; (2) at a prominent butte $1\frac{1}{2}$ miles north of Kenton; (3) in a small patch where Sections 4, 5, 8, 9, of T. 5 N., R. 2 E., join; (4) in a long narrow strip a short distance west of the Gallinas; and, (5) in a long winding exposure north of Black Mesa on North Carrizo Creek. Recent work has shown this last exposure to be the top part of the Triassic (Dockum formation). The discovery of this and other errors led De Ford,⁵ in 1927, to suggest the advisability of a detailed study of the region. Since 1931 the writer has given considerable attention to the area, and in the summers of 1936-37 prepared a detailed geologic map of the Cimarron River valley from the New Mexico-Oklahoma state line eastward to the place where that river leaves Oklahoma. The map (Fig. 1) reproduced in this paper includes only that portion of the Cimarron River valley in Oklahoma in which the Morrison is exposed.

GENERAL STRATIGRAPHY

Since a detailed report, now in preparation by the writer, on the geology of the Cimarron River valley in Oklahoma will soon be ready for publication, only a very brief account of the general stratigraphy of the area is given at this time.

² W. T. Lee, "The Morrison Shales of Southeastern Colorado," *Jour. Geol.*, Vol. IX (1901), pp. 343-52.

³ "The Morrison Shales of Southern Colorado," *ibid.*, Vol. X (1902), pp. 36-58.

⁴ E. P. Rothrock, "Geology of Cimarron County, Oklahoma," *Okla. Geol. Surv. Bull.* 34 (1925).

⁵ Ronald K. De Ford, "Areal Geology of Cimarron County, Oklahoma," *A.A.P.G. Bull.*, Vol. XI (1927), Part II, pp. 753-55.

TABLE 1
GEOLOGIC SECTION OF THE CIMARRON RIVER VALLEY

Formation			Description	Feet	
CENOZOIC	Quaternary	Recent	Wind-blown sand and stream deposits	2-15	
		Pleist.	Panhandle	Wind-blown sand	1-40
			Girty	Stream deposits	1-20
	Unconformity				
	Tertiary	U.Plio.	Basalt	Black to grayish green	66
			Ogalalla	Sand, gravel, mortar beds	5-50
MESOZOIC	Cretaceous	Unconformity			
		Graneros	Sandstone, shale, limestone	135	
		Dakota	Massive, buff, cross-bedded, conglomeratic sandstone	185	
		Disconformity			
		Purgatoire	Massive, buff sandstone capped with black to gray fossiliferous shale	99	
	Jurassic	Unconformity			
		Merrison	Variously colored sandstone, shale, and limestone	465	
		Exeter	Massive, white sandstone	18	
		Unconformity			
	Triassic	Dockum	Variegated sandstone, shale	66	
Minimum thickness				1,043	

The Dockum formation of the Triassic is the oldest series of rocks exposed in the area. This may be seen to underlie the Exeter (Jurassic) with slight angular unconformity, immediately southeast of Tate Butte. Nine miles west of the Oklahoma-New Mexico state line the angle between the two formations is much greater, being probably 20° . The Dockum consists of gray and maroon sands and clays, agreeing in this respect with the Dockum of Big Spring, Texas, and elsewhere. Sixty-six feet of the formation are exposed at Tate Butte.

The Exeter is dominantly a white, massive sandstone about 18 feet thick. It is well exposed at Tate Butte and at the New Mexico-Oklahoma state line on Highway 64. It is also present north of Boise City, Oklahoma, where, however, there are no good exposures.

The Morrison rests conformably on the Exeter and is the most widespread surface formation in the valley of the Cimarron. Lee's⁶ description, "uniformly variable," is most applicable, for the formation varies rapidly vertically and horizontally. The total thickness is about 465 feet. At several localities the bedding of the Morrison makes a decided angle with that of the overlying Purgatoire of the Lower Cretaceous.

The Cheyenne, the lowest member of the Purgatoire, is a buff, conglomeratic sandstone. This member contains many fossilized logs and fragments of wood. It forms numerous bluffs along the outer limits of the valley. The maximum measured thickness was 66 feet. The Kiowa, which is the upper part of the Purgatoire, is a gray to black shale with considerable platy sandstone. The shale is highly fossiliferous, containing large numbers of *Gryphaea corrugata* Say. The greatest thickness measured was 49 feet. The top of the Purgatoire is channeled in many places, thus indicating an erosion interval prior to the deposition of the Dakota.

The Dakota is a massive, cross-bedded sandstone. The greatest thickness (185 feet) is found immediately south of the main canyon and west of the old town site of Mineral. There it has a threefold character. The lower 85 feet are a massive, cross-bedded, conglomeratic sandstone, which forms conspicuous bluffs on each side of the canyons. Above this is a 1-foot layer of lignite, followed by 46 feet

⁶ *Jour. Geol.*, Vol. IX (1901), p. 36.

of grayish shale and ferruginous sandstone. The next 53 feet closely resemble the lowest 85 feet, being a cross-bedded, conglomeratic sandstone.

The Graneros is conformable on the Dakota and is composed of 135 feet of sandstone, shale, and fossiliferous limestone. It contains plesiosaur bones, shark teeth, and *Inoceramas* fragments. The Graneros is the highest division of the Mesozoic in the area.

The Tertiary is represented by the Ogalalla (Upper Pliocene) sands, gravel, and typical mortar beds. The thickness probably does not exceed 55 feet. The average is about 20 feet.

The only igneous rocks in the area are black lavas of Tertiary age which form a conspicuous mesa, known as Black Mesa, about $2\frac{1}{2}$ miles north of Kenton, Oklahoma.

The Quaternary is represented by Pleistocene and Recent stream and wind-blown sand. These sediments are not very thick and are highly lenticular. In a few places they contain the remains of *Elephas columbi*. The term "Girty" is well established for Pleistocene stream deposits, but no name has previously been applied to the wind-blown and loesslike deposits of the southwest. For convenience such deposits are here termed "Panhandle." This name is appropriate because of the extensive deposits of wind-blown sand in the panhandles of Texas and Oklahoma.

STRUCTURE

The panhandle of Oklahoma has been affected by the same movements which disturbed the Rocky Mountains and the foothills to the east. There were several of these disturbances; but in Oklahoma only minor folds, of various orientation, were produced. The first uplift, for which there is evidence in the area, occurred after the close of the Triassic (see Fig. 2). At Tate Butte, and in a more pronounced way at Battleship Butte, a few miles west of Kenton in New Mexico, the Dockum is overlain with marked angularity by the Exeter. In the Tate Butte-Robbers' Roost locality the dip of the Morrison increases from 4° to 7° to the southeast. The next marked disturbance in this region occurred after the close of Jurassic time, when the Morrison was uplifted with warping and truncation. Another minor uplift led to stream channeling in the Purgatoire. Other

slight disturbances occurred in Pliocene time. The two most pronounced folds are located at the opposite ends of the area studied. The westernmost centers just west of the Oklahoma-New Mexico state line north of Black Mesa. This flexure is a dome which has been involved in two well-marked periods of uplift and in two or three less intense disturbances.

The largest structure of the area lies north of Boise City, Oklahoma, on the Cimarron River. This fold is somewhat dome-shaped, symmetrical, and attains a maximum dip of about 10° . The greater axis is in a north-south direction.

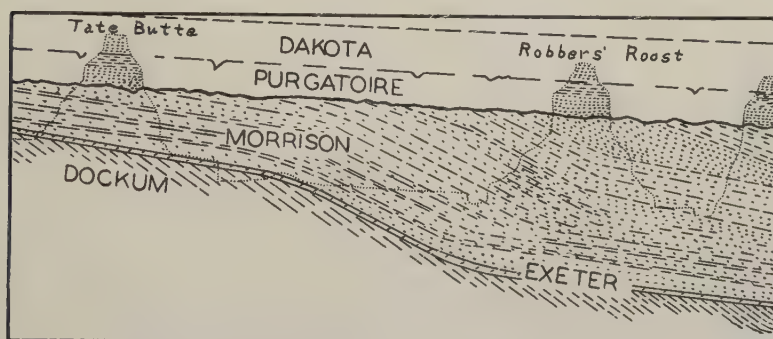


FIG. 2.—Relationship of the Morrison at Tate Butte and Robbers' Roost. Sequence of events in the diagram are: deposition of the Dockum, followed by uplift and planation; subsidence and deposition of the Exeter and Morrison, after which occurred uplift and partial erosion of those sediments, followed by subsidence and deposition of the Purgatoire and Dakota. The heavy line represents the post-Morrison surface; the dotted line, the present surface.

Other smaller anticlinal folds involving the Morrison are found in many places. Some of the most notable are: (1) on both sides of the Gallinas Creek; (2) east of the Joe Brown Ranch; (3) north of Boise City and to the west of Highway 38. The anticlines east and west of the Gallinas Creek, which occupies a syncline between them, have their axes northwest and southeast. The east and west dips are about equal and do not exceed 7° . The eastern fold extends from the Hallock Ranch into Colorado for a distance of almost a mile. The western fold is slightly broader and longer, extending from the Cimarron River into Colorado for a short distance. The fold east of the Joe Brown Ranch is symmetrical and has a northeast-southwest

strike. The dip is about 7° . The small folds north of Boise City are asymmetrical, probably having resulted from solution of strata slightly below the surface. Some of these small folds are very close together with no agreement in the direction of the strike.

DETAILS OF THE MORRISON FORMATION

The Morrison here, as elsewhere, is composed of variegated sands, shales, and a few limestones. The color, lithology, and chemical composition vary laterally and vertically, as has been pointed out by Lee.⁷ The color ranges from purple, red, brown, yellow, buff, and turquoise-green to white.

The upper 90 feet of thin platy sands and shales of the Morrison were deposited under conditions which suggest frequent and sudden changes in the sedimentary processes involved. At Robbers' Roost the top 115 feet of that formation are composed of very fine, cross-bedded, and apparently wind-blown sand. The most striking difference between the top 90 feet of Morrison and that portion of the formation which lies beneath the massive white sandstone is the greater thickness of the individual layers of the latter. Conditions of deposition were consistently variable. As a rule, beds of coarse sand alternate with layers of fine sand and silt. Apparently, the coarse sand was deposited by currents of increased velocity due to flooded conditions of the streams. The layers of finer material were deposited when the streams in flood lost their velocity. A few lenses of dolomite and limestone apparently accumulated in shallow lakes.

As was stated above, the Morrison is the most widespread formation in the canyons of this region. It not only forms the floor of most of the canyons but rises high in their walls. In the western end of the area, on the north and south sides of Black Mesa, it appears as a band adjacent to the younger formations. From Kenton eastward it occupies the valley of the Cimarron River and its tributaries from wall to wall, except where masked by alluvium. The Morrison may be seen from 1 to 7 miles up the tributaries of the Cimarron River, and on the Gallinas Creek into Colorado for a distance of 2 miles.

⁷ W. T. Lee, "Correlations of Geologic Formations between East Central Colorado, Central Wyoming, and Southern Montana," *U.S. Geol. Surv. Prof. Paper*, 149 (1927), p. 17.

Rothrock reported a maximum thickness of 55 feet for the Morrison in Oklahoma.⁸ Unfortunately, the sediments from which this section was measured lie beneath the Exeter. Lee's measurements include the Purgatoire and are excessive to that extent at the location measured by him.⁹ Lee did not measure the Morrison at the Tate Butte-Robbers' Roost location. He was not, therefore, familiar with the eastward thickening of the Morrison in that region. For Union County, New Mexico, Darton estimated the total thickness of the Morrison to be 362 feet,¹⁰ but apparently he included the Exeter and a part of the Dockum group in that measurement. He says:

One sandstone which lies considerably below the middle of the formation has been called the Exeter sandstone by Lee. I am confident that it is the same bed which appears continuously in the southwestern part of Union County and in the eastern part of San Miguel County in the middle of the Morrison formation but here increased somewhat in thickness.¹¹

Mook has given very careful study to the Morrison in both western Colorado and in Utah. In those regions his measurements show that formation to be about 1,000 feet thick.¹² While the thickness of the Oklahoma section does not approach that of the section measured by Mook, it is greater than the general average for the formation. There is, however, no complete section of Morrison exposed at any one place in Oklahoma; and, in order to get the total thickness, measurements must be combined from three different locations. At Tate Butte there is a thickness of 156 feet. The green shale, which is the top of the Morrison at that location, is carried by a southeast dip to the bed of North Carrizo Creek at Robbers' Roost, where the formation is 219 feet thick. One and one-half miles east of Robbers' Roost, an additional 90 feet are found. The Oklahoma Morrison, therefore, has a total thickness of 465 feet.

The following sections represent the total thickness of the Morrison in the area and show its variable character. The upper and

⁸ Rothrock, *op. cit.*, p. 31.

⁹ *Jour. Geol.*, Vol. X (1902), p. 32.

¹⁰ N. H. Darton, "'Red Beds' and Associated Formations in New Mexico," *U.S. Geol. Surv. Bull.* 794 (1928), p. 307.

¹¹ *Ibid.*

¹² C. C. Mook, "A Study of the Morrison Formation," *Annals New York Acad. Sci.*, Vol. XXVII (1916), p. 157.

lower limits of the formation were confirmed in the field by Mr. Robert H. Dott, director of the Oklahoma Geological Survey, and by Mr. Arthur Wedel, of the Pure Oil Company of Tulsa, Oklahoma.

The thick sandstone at the top of the Morrison at Robbers' Roost does not appear beyond the Gallinas Creek. From there eastward it is the lower part of the Morrison, beginning in the zone of the alternating buff sandstone and purple shales, which is seen in the

TABLE 2
MORRISON SECTION AT TATE BUTTE
S.W. $\frac{1}{2}$ Sec. 21, T. 6 N., R. 1 E.

Top	Feet	Inches
Purgatoire-Morrison unconformity		
Alternating beds of green shale and sand, varying in color from buff to brown, talus covered	54	....
Dove-colored, very dense limestone, occurring in layers about 8 inches thick. Layers separated by zones of green shale. Top grades into sandstone. Surface of limestone irregular. Limestone shows many lenses of chert.	40	....
White, massive sandstone	34	....
Thin-bedded sandstone and shale. Becomes more massive toward the south, where thick sandstone is in evidence. . . .	20	....
Dove-pink dolomite, containing many small dolomite rhombs. . .		8-20
Thin-bedded, buff sandstone, containing numerous, easily eroded, bands	8	....
Total thickness at Tate Butte	156	8-20

escarpments along the Cimarron River and its tributaries. In the eastern part of Ranges 2 and 5 some of the low, rounded hills are capped with the limestones similar to those found just above the bed of the North Carrizo Creek.

As shown in Figure 2, the section of the Morrison measured at Robbers' Roost forms a series of rocks higher in the formation than those at Tate Butte to the northwest, owing to the southeasterly dip, which increases from 4° at Tate Butte to 7° at Robbers' Roost. This dip carries the top member of the Morrison at Tate Butte to the bed of the North Carrizo at Robbers' Roost. At the creek level there is an emerald-green shale which corresponds to the top of the Morrison at Tate Butte and at 101 Hill.

The top member of the Morrison at Robbers' Roost is a 115-foot

layer of white, cross-bedded sandstone, which lies immediately beneath the marked unconformity at the base of the Cheyenne sandstone. One and one-half miles southeast of Robbers' Roost these white sandstones of the Morrison are overlaid conformably by a 90-foot layer of Morrison shale, which in turn is topped unconformably

TABLE 3
MORRISON SECTION AT ROBBERS' ROOST
Sec. 34, T. 6 N., R. 1 E.

Top	Feet	Inches
Purgatoire-Morrison unconformity		
White, cross-bedded sandstone	115	....
Buff, brown-flecked, conglomeratic sandstone	16	....
Alternating layers of brown, platy sandstone, red-to-purple and gray-to-green shale	39	....
White, brown-flecked, cross-bedded sandstone, containing a 2-foot layer of purple shale 6 feet from the top. Ledge-forming	22	....
Variegated, thin-bedded, alternating layers of white, buff, gray sandstone; purple-to-dove-colored dolomite and limestone; greenish shales, occupying the bed of the North Carrizo Creek	27	....
Total thickness	219	....

TABLE 4
UPPER MORRISON SHALE
Sec. 11, T. 5 N., R. 1 E.

Top	Feet	Inches
Purgatoire-Morrison unconformity		
Alternating layers of variously colored sandstone and shale.		
Too badly covered with talus to be measured	90	....
Total thickness	90	....

by the conglomeratic sands of the Cheyenne. Thus, the Cheyenne overlies, successively from west to east, Morrison shales which occur well down in the section at two localities; the thick, white sandstone; and finally the top 90-foot layer of shale, establishing beyond a doubt the unconformable relationship of the Purgatoire to the Morrison.

Some of the sandstone members of the Morrison have been converted into quartzite, which is usually near the top of the formation

and has some value as a marker. In the valley between Black Mesa and Kenton one of these quartzites has been tilted to an angle of 12° . Where there is quartzite and where the younger rocks have been removed, it forms hills covered with quartzite "float."

When the quartzite was first studied at the thick exposure north of Kenton, the writer supposed the cementation to be the result of metamorphism by heat from the lava of Black Mesa, which may have formerly covered it. A closer study indicated that the zone of siliceous cementation is of varying thickness, usually penetrating along bedding and fracture planes. This evidence indicates that the quartzite has resulted from deposition of silica, as a cementing material, by meteoric waters.

AGE OF THE MORRISON

It is now generally agreed that the Morrison is Jurassic in age, and the evidence presented in the preceding discussion supports this view. Folding and erosion following the Triassic, and again preceding the earliest-known Cretaceous, in addition to the fact that the Morrison may be considered as a stratigraphic unit, indicate the Jurassic age of that formation.

STRATIGRAPHIC POSITION OF THE BONES

The Morrison has few divisions in the Cimarron River basin which can be traced laterally for any great distance. At Quarry No. 1, on Highway 64, 8 miles east of Kenton, where the following section was measured, there is a buff, very dense sandstone which occurs about 7 feet above the dinosaur bones. This sandstone, however, cannot be distinguished from any of six similar ledge-forming sandstones at Robbers' Roost, the lowest of which lies 168 feet below the top of the Morrison remaining at that location and the highest of which is 32 feet above the lowest. The bone horizon, lying somewhere within this series, should have been from 290 to 324 feet below the top of the original Morrison, provided, of course, that that formation does not become appreciably thinner in the intervening distance. A similar brown sandstone is about the same distance above the bones at dinosaur location No. 2, which is about 1 mile north of Quarry No. 1, and at location No. 3, which is about 3 miles northeast. At locations No. 4 and No. 5, $1\frac{1}{2}$ miles west of Kenton,

the bone-producing layer is ashy gray and the bones are silicified. Here, too, because of the lateral variation of the Morrison, the distance below the top of the formation cannot be very closely determined. Location No. 6 is on the Oklahoma-Colorado state line on the Tucker farm north of Kenton. The bone layer is stratigraphically similar to all of the others and, like them, cannot be placed exactly in the section.

TABLE 5
MORRISON SECTION AT QUARRY NO. 2
Eight Miles East of Kenton on Highway 64

Top	Feet	Inches
Purgatoire-Morrison unconformity		
Thin-bedded, buff sand, almost quartzitic in places, separated from underlying clays by an irregular surface.	2	....
Cream-colored shale, banded with light purple.	1	....
Purple banded shale with lenses of light-colored hard material	2	4
Dense, purple, hard shale, forming a distinct band of irregular upper and lower surface.	1	5
Gray shale. Contains many concretions and dinosaur bones. . .	8	6
Alternating layers of purple, gray, and buff shales, from a few inches to 6 feet in thickness. The lowest one is emerald green and shows in the bed of the Carizzo Creek.	35	....
Total thickness.	50	3

From Robbers' Roost eastward, buff, ledge-forming sandstones, with which the bones are associated, are found in isolated patches as far as the Kohler farm. One seldom finds more than two or three of the ledges exposed at any one place.

So much lateral variation in the thickness and character of the Morrison suggests changing conditions from place to place, although the unbroken condition of the bones indicates that no marked disturbances have affected them. The fact that they are disarticulated and, in the main, undistorted indicates that they were disturbed only by streams of water and possibly by flesh- or carrion-eating animals. The large size of many of the bones would require a stream of considerable force to move them. Their perfect condition, their degree of concentration, and the fact that an occasional two or three bones are normally articulated suggest that they were moved only a few feet at the most.

DINOSAURS OF THE MORRISON IN OKLAHOMA

It is impossible to give a description of all of the bones excavated at Quarry No. 1 at this time. Most of them are still in their matrix and plaster casts. This discussion will, therefore, be confined to the data necessary to establish, tentatively, the presence of the following four genera: *Ceratosaurus*, *Brontosaurus*, *Camptosaurus*, and *Stegosaurus*.

Ceratosaurus? MARSH

The evidence for the presence of *Ceratosaurus* bones in Quarry No. 1 is inadequate for more than a questionable identification. Several teeth similar to the one shown in Figure 3 (5), a fragment of three fused metatarsals, a small cervical vertebra (Fig. 3 [7]), two relatively small hollow dorsal vertebrae, a number of broad-headed, and tapering ribs from 12 to 20 inches in length (Fig. 3 [9]), suggest an animal of the size and character of *Ceratosaurus*.

Brief descriptions of the bones follow:

Teeth.—The teeth are strong and compressed, with good cutting edges. The fragments present average about 5.1 cm. in length.

Metatarsals.—The fragment of metatarsals consists of the proximal ends of the fused second and third metatarsals with a part of the fourth broken away. The birdlike character of these bones is well demonstrated. The fragment is 10.2×15.3 cm. See Figure 3 (6).

Cervical vertebra.—This bone is flat on the anterior end and convex on the posterior end. It has strong neural arches, a short dorsal spine, and well-developed zygopophyses. Its total length is 8.9 cm.

Dorsal vertebrae.—These bones are not complete but are well-enough preserved to reveal something of their true character. The sides and the bottom are deeply excavated, suggesting an hourglass, except for the dorsal region, where the centrum is expanded to receive the neural arches. Broken places reveal a large internal cavity. The centrum is depressed along the neural canal. The upper half of the dorsal spine has been restored in Figure 3 (8). The length of the centrum is 12.4 cm.

Ribs.—The ribs are broad headed and taper to the distal end. If it were not for the presence of the bones described above, these ribs alone would be of little diagnostic value, since they might be confused with those of other small theropods. See Figure 3 (9).



FIG. 3.—(1) An individual tooth of *Brontosaurus excelsus* Marsh, length 13 cm. (2) A fragment of the right mandible of *B. excelsus* Marsh, length 35 cm., depth 23 cm. (3) A dorsal vertebra of *B. excelsus* Marsh, greatest length 130 cm. (4) The left femur of *B. excelsus* Marsh, length 178 cm. (5) A fragment of tooth of *Ceratosaurus?* Marsh, length 5.1 cm. (6) A fragment of the fused metatarsals of *Ceratosaurus?* Marsh, size of fragment 10.2×15.3 cm. (7) A small cervical vertebra of *Ceratosaurus?* Marsh, length 8.9 cm. (8) A dorsal vertebra of *Ceratosaurus?* Marsh, length 12.4 cm. (9) A rib of *Ceratosaurus?* Marsh, length 32.5 cm. (10) Front view of the left femur of *Camptosaurus?* Marsh, length 69 cm. (11) A side view of the left femur of *Camptosaurus?* Marsh, length 69 cm. (12) A dorsal plate of *Stegosaurus* Marsh, greatest length 38 cm. (13) A femur of *Stegosaurus* Marsh, length 113.5 cm.

Brontosaurus excelsus MARSH

A large number of *Brontosaurus* bones have been removed from Quarry No. 1. These bones are remarkably complete, although a slight movement in the sediments has fractured them in a few places.

Teeth.—The teeth identified as those of *Brontosaurus* are characteristically spoonlike. The enamel-covered portion has many longitudinal ridges, and in this respect it closely resembles *Morosaurus* as figured by Marsh.¹³ The root of the tooth found in the Oklahoma quarry is a little less bulbous than that of *Morosaurus*. The teeth agree closely with those of *Brontosaurus* as figured by Marsh.¹⁴ Individual tooth, 13 cm. long. See Figure 3, (1) and (2).

Vertebrae.—The vertebrae are massive and have numerous cavities in the centra. The specimen seen in Figure 3 (3) is a dorsal, the centrum of which measures 16 inches in width. Numerous opistho-coelus vertebrae were found. Greatest length, 130 cm.

Scapulae.—Two very large scapulae from Quarry No. 1 have been identified as belonging to *Brontosaurus*. These scapulae differ slightly in length and width, but the discrepancies are so small that the writer presumes that they belong to the same animal. The upper portion of the scapula is long and narrow without lateral expansion. The proximal end closely resembles *Morosaurus*, but the latter has an expansion toward the upper end. The total length of the long scapula is 138 cm.

Femora.—Both femora are present, and one is almost perfect. The bone is solid, and all trochanters are greatly subdued. The head of the femur has no neck, and the condyles are rounded and much wider than the shaft. The complete femur measures 178 cm. in length. See Figure 3 (4).

On the evidence presented above, this specimen has been identified as *Brontosaurus excelsus* Marsh.

Camptosaurus? MARSH

This genus is represented by several bones which are of small diagnostic value. Identification was based upon a single femur.

¹³ O. C. Marsh, unnamed series of plates, *Amer. Jour. Sci.*, Vol. XVI (1878), Pl. V, Figs. 1 and 2.

¹⁴ "Dinosaurs of North America," *U.S. Geol. Surv. 16th Ann. Rept.* Part I (1898), Pl. XX.

Femur.—This bone is relatively massive, measuring 69 cm. in length. The smallest diameter of the shaft is 13 cm. It is markedly curved, has a slightly inflected head, and broad articulating surfaces for the tibia and fibula. A third trochanter occurs on the inside slightly below the middle of the shaft. See Figure 3, (10) and (11). The femur of *Laosaurus*, with which this specimen might be confused, is less massive and has the internal trochanter relatively high on the shaft.

Stegosaurus MARSH

The only bone from Quarry No. 1 identified as that of *Stegosaurus* is a dorsal plate. Many metapodials, vertebrae, and phalanges from that quarry have not been identified. The plate came from the outer margin of the quarry, and it is thus probable that more of the animal may be present in the quarry or in the unidentified bones. An almost perfect femur of *Stegosaurus* was found at location No. 3. See Figure 3 (13).

Dorsal Plate.—This plate is about 25×35 cm. and is typical of the genus.

Femur.—The femur is slender and straight. The head is well rounded, and there is virtually no neck. The condyles are separated by a very shallow sulcus. This bone shows no third trochanter. Length, 113.5 cm.

SUMMARY

In a detailed study of the Cimarron River Valley of Oklahoma the known exposed area of the Morrison formation has been extended from a few isolated patches in the western end of the area to a total of more than 105 square miles. The formation agrees in its general character with the Morrison formation wherever it is found. The full thickness (465 feet) is much greater than that previously reported for the Morrison in this and neighboring regions. This fact indicates deposition on a rather steep slope or a greater eastward extension of the Morrison than was generally supposed.

While no vertebrates, other than the dinosaur bones, have been found, six scattered deposits of the remains of these animals indicate considerable local abundance. In Quarry No. 1 the bones are numerous, though dissociated. In this respect they are similar to those at

Quarry 9 at Como Bluff, Wyoming. At Como Bluff, however, eleven genera of dinosaurs have been determined, whereas at the Oklahoma quarry only four genera have been identified. Further laboratory work may bring other genera to light.

The field work has revealed a striking unconformity between the Morrison and the overlying Purgatoire. And although the Morrison is conformable on the Exeter, the Exeter is thin and in turn rests on the Dockum with angular relationship. It is thus evident that all the Mesozoic systems are represented in the Oklahoma Panhandle and adjacent parts of New Mexico and Colorado.

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